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MAVIS III — A Windows 95/NT Upgrade

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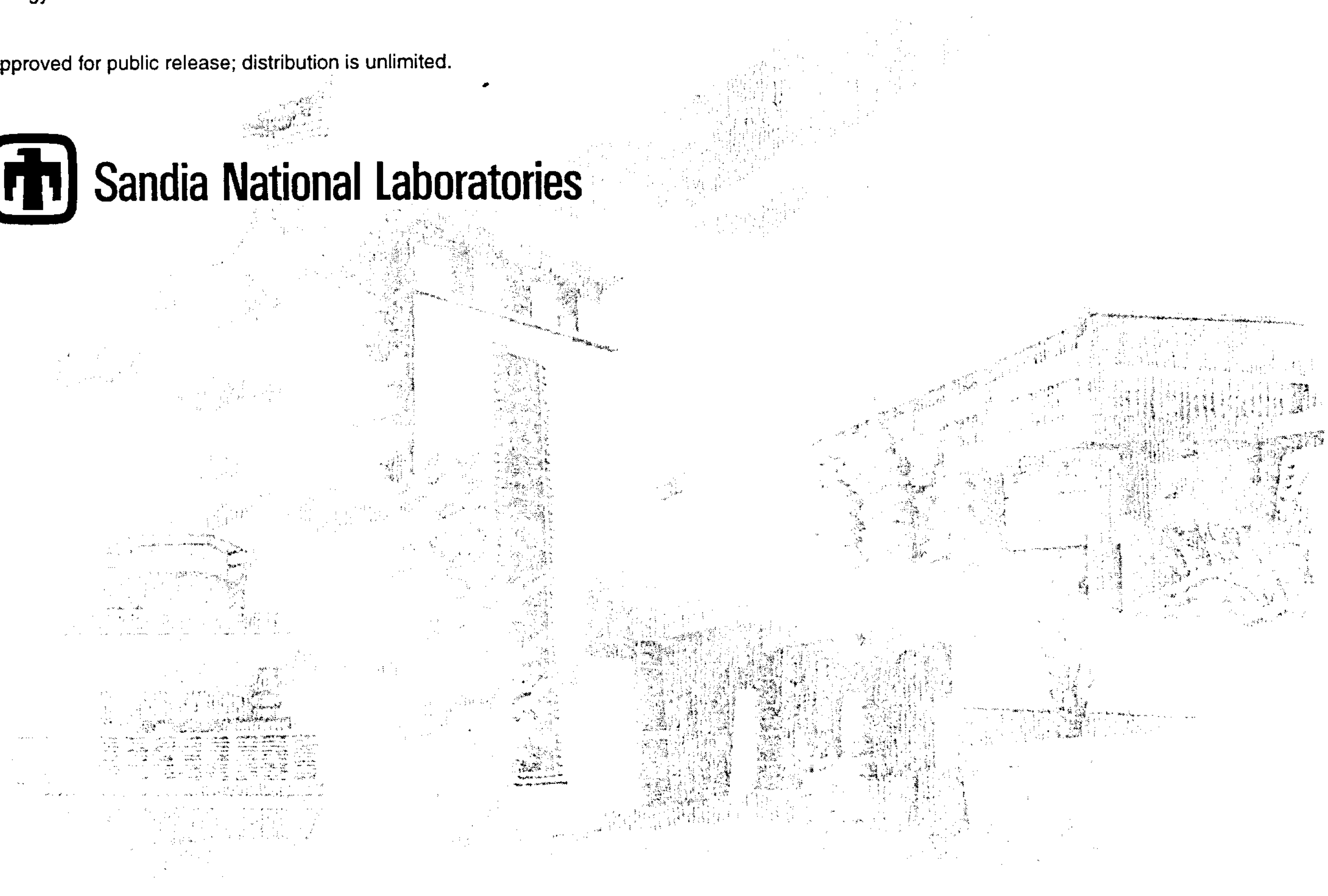

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MAVIS III – A Windows 95/NT Upgrade

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Abstract

MAVIS (Modeling and Analysis of Explosive Valve InteractionS) is a computer program that simulates operation of explosively actuated valves. MAVIS was originally written in Fortran in the mid 1970's and was primarily run on the Sandia Vax computers in use through the early 1990's. During the mid to late 1980's MAVIS was upgraded to include the effects of plastic deformation and it became MAVIS II. When the Vax computers were retired, the Gas Transfer System (GTS) Development Department ported the code to the Macintosh and PC platforms, where it ran as a simple console application. All graphical output was lost during these ports. GTS code developers recently completed an upgrade that provides a Windows 95/NT MAVIS application and restores all of the original graphical output. This upgrade is called MAVIS III version 1.0. This report serves both as a user's manual for MAVIS III v 1.0 and as a general software development reference.

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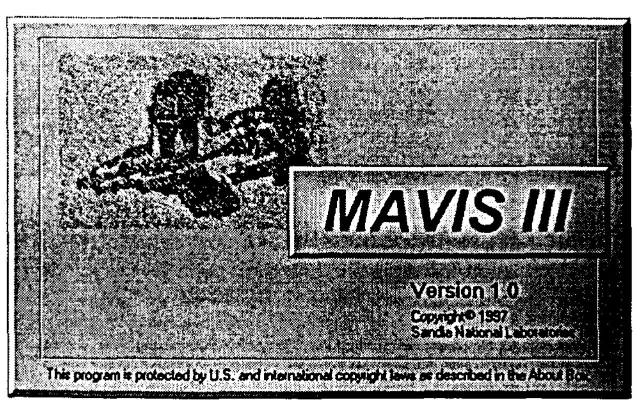
Executive Summary

MAVIS (Modeling and Analysis of Explosive Valve InteractionS) is a computer program that simulates operation of explosively actuated valves. These valve assemblies generally comprise an electrically initiated explosive actuator, shear disk, plunger, housing, and tubes. In operation, pressure generated by the actuator shears the disk and drives the plunger down a bore in the housing. As it travels down the bore, the plunger cuts the tubes, opening a flow path, and continues until it becomes wedged into a taper in the housing bore. The housing taper stops the plunger at the desired location and forms a seal to prevent gas leaks through the actuator threads.

In a broad sense the code is relatively simple; it numerically integrates F=ma for plunger motion. The code sophistication lies in determining the magnitude of all important forces acting on the plunger as it travels down the bore. Important features included in the physical model are the explosive equation-of-state, the elastic and plastic interactions between the housing and plunger, static and dynamic friction, tube cutting forces, and trapped gas forces.

MAVIS was originally written in Fortran in the mid 1970's and was primarily run on the Sandia Vax computers in use then and through the early 1990's. During the mid to late 1980's MAVIS was upgraded to include the effects of plastic deformation and it became MAVIS II. Shortly after, Sandia's corporate computing strategy changed and the Vax computers became less and less accessible. To maintain an analysis capability, the Gas Transfer System (GTS) Development Department ported the code to the Macintosh and PC platforms, where it ran as a simple console application. All graphical output was lost during these ports. GTS code developers recently completed an upgrade that provides a Windows 95/NT MAVIS application and restores all of the original graphical output. This upgrade is called MAVIS III version 1.0.

This report serves both as a user's manual for MAVIS III v 1.0 and as a general software development reference. The intent of the software description is to help other developers understand the development philosophy and software structure so that bugs may be more easily eliminated and future upgrades may be simplified.



User's Manual

Scope

This user's manual is not intended as a comprehensive guide to the physical models implemented in the MAVIS code. Model specific information can be found in references 1, 2, and 3. This manual serves only to describe how to use the Windows 95/NT MAVIS III upgrade.

Overview

MAVIS (Modeling and Analysis of Explosive Valve InteractionS) is a computer program that simulates operation of explosively actuated valves. These valve assemblies generally comprise an electrically initiated explosive actuator, shear disk, plunger, housing, and tubes as shown in Figure 1.

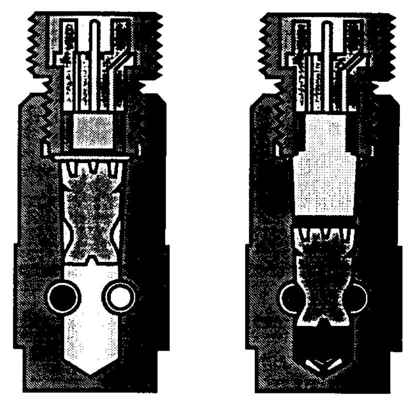


Figure 1: Valve Operation

In operation, an electrical signal initiates explosive burn. High-pressure combustion products apply an increasing load to the disk that seals the bore above the plunger. When the load is sufficiently high, the disk shears and pressure is applied to the plunger, which accelerates down the bore in the valve housing. During this time the explosive continues to burn, generating more combustion gases and tending to increase the pressure load behind the plunger. At the same time, however, the plunger moves away from the actuator, increasing the volume occupied by the combustion products and tending to lower the pressure. MAVIS accounts for both effects when determining the magnitude of this pressure load.

As the plunger travels down the housing bore it contacts and shears one or two tubes, opening a flow path. MAVIS calculates these tube-cutting forces, which are a function of the tube mechanical properties and geometry. MAVIS also accounts for pressure forces acting to decelerate the plunger due to gas trapped in the bore or in the tubes.

With a properly designed valve, the plunger comes to rest as it wedges into a taper in the housing bore. The forces that bring the plunger to rest include both the axial component of the geometric interference forces and the friction generated at the sliding interface. While the original version of MAVIS included only elastic interference forces, an upgrade performed in the early 1990's included forces due to plastic deformation as well.

In a broad sense the code is relatively simple; it numerically integrates F=ma for plunger motion. The code sophistication lies in determining the magnitude of all important forces acting on the plunger as it travels down the bore. At each time step taken by the numerical integrator, all applicable forces cited above are summed and applied to the plunger. The resulting acceleration for that time step is then determined and velocity and position resolved by further integration.

Code History

Raymond Ng wrote the original MAVIS in 1975 and provided Sandia's first analytical tool for rapid evaluation of explosively actuated valve parameters. The I/O structure of this original code, which was written in Fortran, was relatively basic. Input was provided on a deck of punch cards and output was delivered to a line printer directly connected to the computer. As the computing environment became more interactive, a *namelist* formatted input file replaced the card deck. Summary output was written to the screen while detailed output went to several different files. This first version of MAVIS included only elastic interactions between the plunger and housing; all material effects were linear. In the mid to late 1980's Sandia worked with the University of Washington to incorporate the nonlinear effects of material plasticity into the physical model. The effort resulted in a sophisticated semi-empirical model that was correlated to a series of finite-element analyses. Experimental work confirmed that this model correctly predicted the plunger kinematic trends introduced by housing plasticity. This first major upgrade to the original code was called MAVIS II.

Shortly after the plastic model upgrade, the Vax computers on which the code ran were relocated to Sandia/NM and over the next few years became less and less accessible. When these computers were finally retired, MAVIS was ported to desktop platforms, first the Macintosh and then the Windows PC. It ran on these platforms in essentially the same manner as it did on the Vax: as a console application. Unfortunately, because the MAVIS II plotting routines required a graphics library that was not available for the Macintosh or Windows platforms, all graphical output was lost. The most recent upgrade, which resulted in MAVIS III, was performed to the PC version of the ported code. During this upgrade, the console application was converted to a Windows 95/NT application with a modern user-interface and all graphical output was restored.

Installation

Because MAVIS is intended to be installed on a limited number of machines, an automated installation program was not developed. Instead, the program is installed manually. This section describes the steps required to successfully install MAVIS on a Windows 95 and NT computer. The required files are shown in Table 1.

Table 1: Required Files

File	Description	Dynamic Link Libraries	
mavis.exe	The main executable	mfc42d.dll	gswdll32.dll
mavisSG1.exe	The computational exe	msvcrtd.dll	dforrt.dll
gsw32.exe	The graphics server	mfco42d.dll	dformd.dll
actuators.mdb	The actuator data base	mfcd42d.dll	
disks.mdb	The shear disk data base	msvcirtd.dll	
plunger.mdb	The plunger data base	gsprop32.dll	
housing.mdb	The housing data base	gswag32.dll	
materials.mdb	The materials data base		

While the main executable, *Mavis.exe*, can be placed wherever the installer desires, the computational executable, *MavisSG1.exe*, and the databases must reside in a specific directory. This directory may be selected by the installer and must be identified to the system in the MAVISDIR environment variable. The graphics server, *gsw32.exe*, can be installed in any directory identified in the *path* environment variable. In addition, since MAVIS uses the Windows accessory *WordPad* to display textual information, the *WordPad* directory must be included in the *path* environment variable. The dynamic link libraries, which represent MFC[1], graphics server, and Fortran run time routines, may also be installed in any directory identified in the *path* environment variable.

Setting the environment variables

Windows 95

1. Using a text editor, edit the *autoexec.bat* file to include the following two lines:

   SET MAVISDIR=*<mavis directory>*
   SET PATH=*<wordpad directory>*;%PATH%

   where *<mavis directory>* is the path to the directory chosen for installation (for example *C:\Applications\Mavis*) and *<wordpad directory>* is the directory in which *Wordpad* is located.

2. Restart the computer.

Windows NT

1. Log onto the target machine as an administrator.
2. Right-click the *My Compute*r icon on the desktop and select *Properties* from the context menu. Select *Environment* from the resulting tabbed dialog to display the environment variable page as shown in Figure 2.
3. Select any variable in the *System Variables* list box and in the *Variable* edit box overwrite it with the following:
4. `MAVISDIR`
5. In the *Value* edit box type the path to the directory chosen for installation, for example:
6. `C:\applications\mavis`
7. Select the `Path` variable in the *System Variables* list box.
8. If not already displayed in the *Value* edit box, add the path to the graphics server, *WordPad*, and dll directories to the path list.

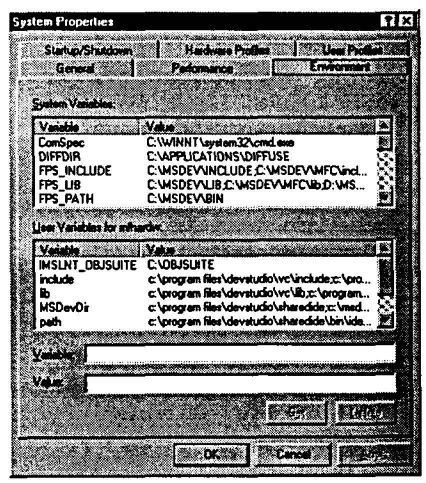


Figure 2: System Properties

[1] Microsoft Foundation Class

9. Click the *Set* button and then the *OK* button.
10. Restart Windows

Copying the required files

1. Copy the main executable, *Mavis.exe*, to any desired directory.
2. Copy the computational executable, *MavisSG1.exe* and the five database files to the directory defined by the MAVISDIR environment variable.
3. Copy all remaining files to the desired directories.

Running MAVIS

1. Run MAVIS by double-clicking the *Mavis.exe* icon or an appropriate shortcut.

MAVIS Display

The MAVIS display is shown in Figure 3. The Mavis main frame, which also displays the name of the currently selected document in its title bar, houses the system menu, toolbar, and main output window. The main output window, in turn, contains two views, the geometry view and the graph view. These two views present the user with all graphical output and describe all aspects of valve operation. The input tabbed dialog, also called a property sheet, provides the user with the means to enter the valve definition, either by inputting individual parameter values or by accessing a set of valve databases. Unlike the main output window, the tabbed dialog is not constrained to remain within the main frame boundaries. It can be moved to any desired location on the screen.

MAVIS allows the user to manipulate multiple sessions (documents) at the same time, a capability that is useful when comparing several different valve designs. Selecting *New* from the *File* menu starts an additional session. The number of concurrent sessions is limited only by the amount of available memory and the user's ability to maintain an understanding of the multiple windows. Although multiple main output windows may be displayed, only a single input tabbed dialog window is shown. The values in the tabbed dialog always correspond to the currently selected main output window.

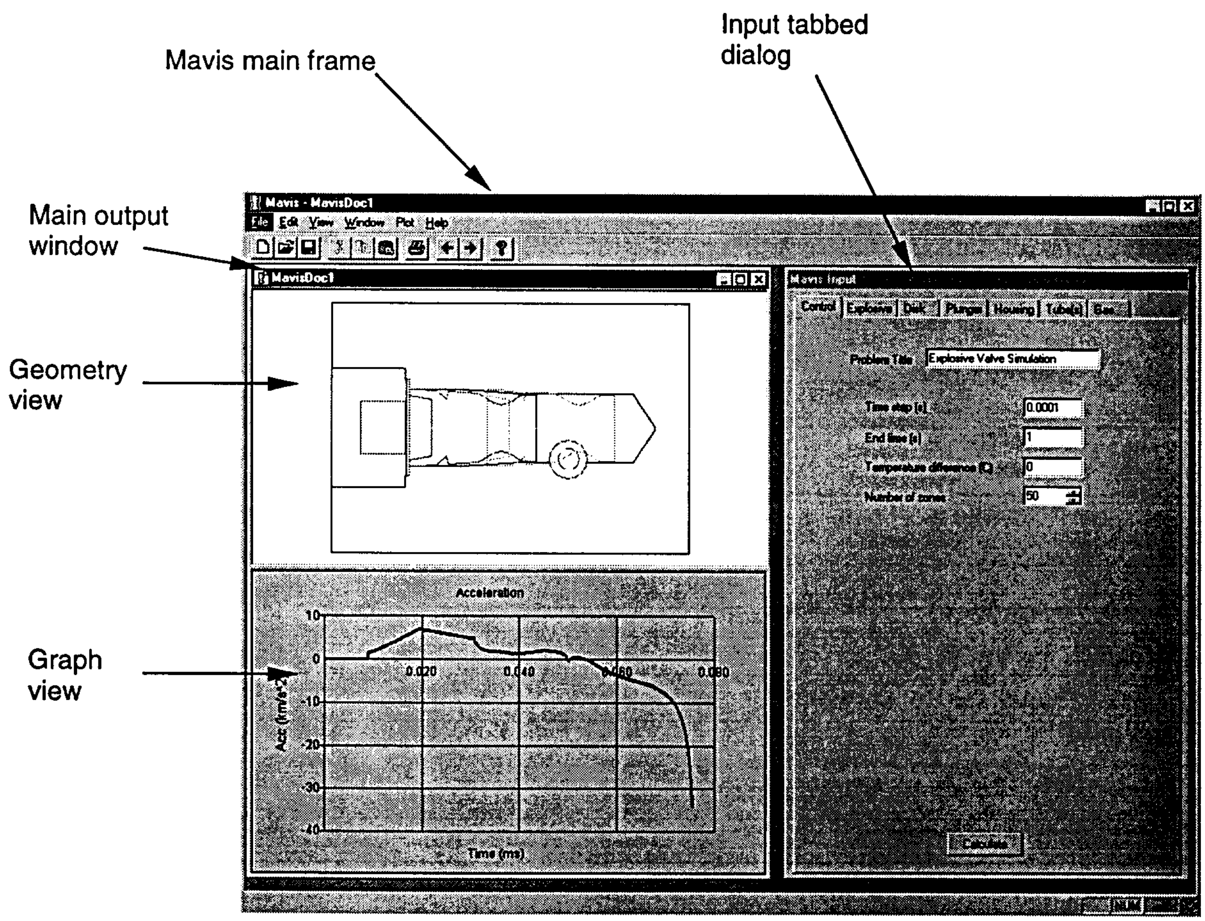


Figure 3: Mavis Display

Data from a MAVIS session may be stored by selecting *Save* or *Save As* from the *File* menu. If the data has not yet been saved or if *Save As* is selected, the system presents the *Save As* dialog that allows the user to select a file name and location for storage. Selecting *Open* from the *File* menu restores saved data. In this case the system presents the *Open* dialog that allows the user to browse for the desired file.

Data in either of the main output window panes (geometry or graph) may be previewed or printed by selecting *Print Preview* or *Print* from the File menu. Note that these items act only on the currently selected pane. Therefore, before using these commands the user should ensure that the desired pane is selected by clicking anywhere in that pane.

The next two manual sections describe the input tabbed dialog and the main output window in more detail.

Input Tabbed Dialog

The tabbed dialog is used to enter information that defines the valve to be analyzed and is by initialized with the parameters appropriate for a typical minivalve[2]. The input tabbed dialog contains seven pages, one for program control data and one for each of six general categories of valve information: the explosive, shear disk, plunger, housing, tubes, and trapped gas. The following sections describe each dialog page.

Control

The *Control* page, shown in Figure 4, allows the user to enter a problem title and parameters that control program execution. The title is simply typed into the *Problem Title* edit box. The integration time step and the maximum simulated time that the calculation is allowed to run are entered in the *Time step* and *End time* edit boxes, respectively. Note that the end time entered by the user may not be reached – the MAVIS simulation ends when the plunger comes to rest in the housing. If the user enters inappropriate data that allows the plunger to continue its motion beyond the end time, the calculation will terminate when the end time is reached.

MAVIS can account for dimensional changes due to function temperatures that are different than the temperatures at which the geometries are defined. The user enters the difference between these temperatures, in Celsius degrees, in the *Temperature difference* edit box. Function temperatures greater than the geometry definition temperature are entered as positive values while those less than the geometry definition temperature are entered as negative values.

During the computational portion of MAVIS, the plunger and housing are numerically divided into zones for processing. The user may enter the number of zones in the *Number of zones* edit box. In general, the default value is a good choice and needn't be changed.

Clicking the *Calculate* button initiates a MAVIS calculation and, if successful, updates the output in the main window.

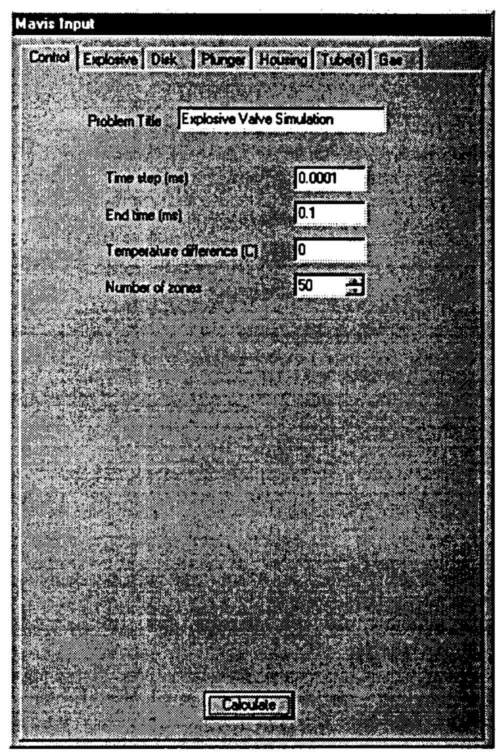


Figure 4: Control Page

[2] A minivalve is a specific class of explosively actuated valves used at Sandia to open flow paths in 1/8" diameter tubes.

Explosive

The *Explosive* dialog page is shown in Figure 5. Here the user enters geometric and material data about the explosive actuator that drives the plunger. As a convenience, this page is linked to an actuator database that contains data for several Sandia actuators. Selecting one of the actuators in the Actuator list box automatically enters all geometric and material parameters. Any individual value may be overridden by entering the desired value in the appropriate edit box. Note that the user is currently unable to transfer data to the database for later recall. The system administrator must update the database as the need arises. The parameters described in this page are shown in Table 2.

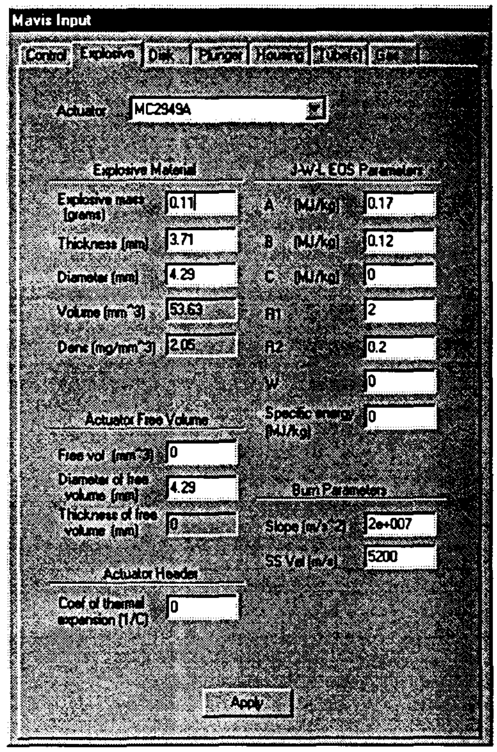


Figure 5: Explosive Page

The *explosive mass* is the mass, in grams, of the explosive material. The *thickness* and *diameter* parameters determine the explosive volume, which is filled by the reaction products and acts to limit the maximum pressure attained by the actuator. The *volume* and *density* are calculated values and change with the mass, thickness, and diameter. The *free volume*, which refers to all unoccupied volume immediately surrounding the explosive, also reduces the maximum pressure. The *diameter* of free volume parameter is used solely in rendering the actuator in the graphical geometry display. The *thickness of free volume* is calculated from the previous two values and is also used only for geometry rendering. The *coefficient of thermal expansion* of the actuator header is used to calculate volume changes due to temperature variations.

JWL EOS refers to the Jones-Wilkins-Lee explosive equation-of-state that MAVIS uses to model expansion of the reaction products.

$$P = \rho\overline{A}\left(1-\frac{W}{R_1V}\right)e^{-R_1V} + \rho\overline{B}\left(1-\frac{W}{R_2V}\right)e^{-R_2V} + \frac{\rho W\overline{E}}{V}$$

where $\boldsymbol{P}$ = pressure (MPa), $\boldsymbol{V}$ = volume ratio, $\boldsymbol{E}$ = specific energy (MJ/kg), ρ = density (kg/m^3), $\boldsymbol{A}$, $\boldsymbol{B}$ = empirical coefficients (MJ/kg), $\boldsymbol{R_1}$, $\boldsymbol{R_2}$ = empirical constants ($R_1 \sim 4.0$, $R_2 \sim 1.0$), $\boldsymbol{W} = c_p/c_v - 1$ at large expansions (usually $0.2 \leq W \leq 0.4$).

The parameters in this section of the dialog are coefficients in the equation and determine the relationship between pressure and volume over a wide range of expansion ratios. Reference 1 contains a more detailed description of the Jones-Wilkins-Lee equation of state and the influence of each of its coefficients.

The final two parameters, *burn front acceleration* and *steady state velocity*, provide explosive reaction rate information. Acceleration refers to the slope of a linear approximation to the initial transient portion of the burn front velocity. Once the initial transient is complete, the burn front becomes constant at the steady state velocity.

Clicking the *Apply* button at the bottom of the page stores the entered data and updates the geometry displayed in the main output window. The data is also automatically saved and the geometry updated when the user clicks a dialog tab to activate a different page.

Table 2: Explosive Parameters

Parameter	Description
Explosive mass	The mass of explosive mixture (g)
Thickness	The axial thickness of the explosive pellet (mm)
Diameter	The diameter of the explosive pellet (mm)
Volume	The volume of the explosive pellet (mm^3) - calculated
Density	The density of the explosive pellet (mg/mm^3) - calculated
Free volume	The amount of unoccupied volume in the actuator (mm^3)
Diameter of free volume	The diameter of the free volume (mm)
Thickness of free volume	The thickness of the free volume (mm) - calculated
Coef of thermal expansion	The coefficient of thermal expansion of the actuator header material ($1/C^\circ$)
A	The A coefficient of the Jones-Wilkins-Lee equation of state (MJ/kg)
B	The B coefficient of the Jones-Wilkins-Lee equation of state (MJ/kg)
C	The C coefficient of the Jones-Wilkins-Lee equation of state (MJ/kg)
R1	The R1 coefficient of the Jones-Wilkins-Lee equation of state
R2	The R2 coefficient of the Jones-Wilkins-Lee equation of state
W	The W coefficient of the Jones-Wilkins-Lee equation of state
Specific energy	The quantity of energy (MJ) released by one kilogram of explosive material (MJ/kg)
Burn front slope	The burn front acceleration (m/s^2)
Burn front SS Vel	The steady state burn velocity (m/s)

Disk

The *Disk* dialog page, shown in Figure 6, allows the user to enter geometric and material information for the shear disk that seals the housing bore above the plunger. This page is linked to two databases, a disk geometry and a materials database. In both categories selecting one of the items in the list box automatically fills all edit boxes. The user can override individual parameter values by typing the desired value into the appropriate edit box. Again, the user cannot currently transfer information from the dialog page to the database. The disk parameters are described in Table 3.

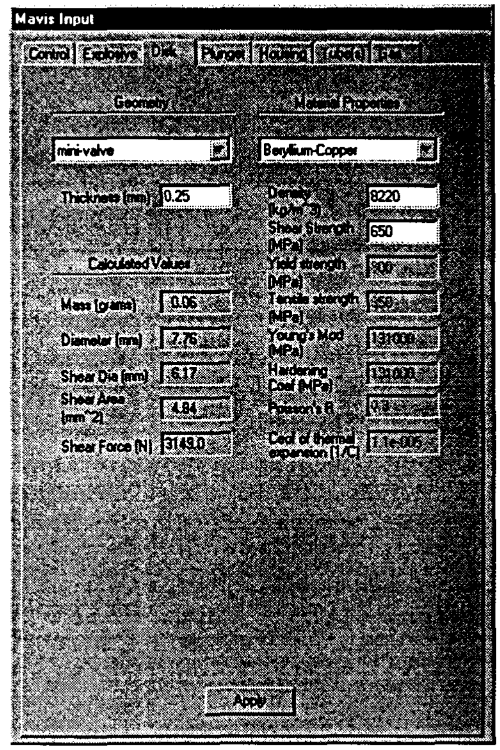


Figure 6: Disk Page

Table 3: Disk Parameters

Parameter	Description
Thickness	The thickness of the shear disk (mm)
Diameter	The diameter of the shear disk (mm)
Density	The density of the shear disk material (kg/m^3)
Shear strength	The shear strength of the shear disk (MPa)
Mass	The mass of the sheared disk (grams) - calculated
Shear Area	The area of the sheared surface (mm^2) - calculated
Shear Force	The force required to shear the disk (N) - calculated

Once the disk is sheared it travels down the housing bore with the plunger and effectively increases the plunger mass. MAVIS assumes that the disk shears at the plunger aft diameter and uses the *thickness* and *density* information to calculate the mass increase. This *mass*, the full *Diameter*, and the *Shear Diameter* are displayed in the *calculated values* section of the dialog. Each changes as the associated inputs change. The full diameter is based on the geometry data entered in the housing page and is used only for rendering the disk on screen. Also shown in the calculated values section are the *shear area* and *shear force.* Since the shear area is based on disk shear at the plunger aft diameter, this dialog refers to the geometry section of the plunger dialog for this value. The shear force is simply the product of the shear area and shear strength. Note that only two of the eight material parameters are enabled for user input. Although selecting a material from the list box fills all eight parameter values, only the two enabled values, density and shear strength, are used in the shear disk calculations.

Clicking the *Apply* button at the bottom of the page stores the entered data and updates the geometry displayed in the main output window. The data is also automatically saved and the geometry updated when the user clicks a dialog tab to activate a different page.

Plunger and Housing

The *Plunger* and *Housing* dialog pages are shown in Figures 7 and 8. Each contains three categories of information: geometry, material, and friction.

The data describing the plunger and housing geometry is entered as a list of x-y coordinate pairs that approximate the cross-section geometry in a piecewise linear manner. Since the geometry is assumed axisymmetric, only one "side" of the 2D cross-section needs to be defined. The data, limited to a maximum of twenty points, is entered in a grid edit structure while a single edit box contains the number of active coordinate pairs. The housing data describes both the internal bore and the external housing geometry. The first data points represent the internal bore. External housing data begins at the first point whose x-value is less than the x-value of the previous point. Unlike the housing geometry, the plunger description does not require both an inner and outer surface definition. Plunger geometry without an interior surface definition implies a solid (non-hollow) configuration. If an interior surface is desired (a hollow plunger), it may be specified following the list of exterior points. MAVIS recognizes the beginning of the interior geometry data when the current x-value is less than the previous x-value

Since the geometry list boxes are linked to corresponding databases, selecting an item from these list boxes automatically fills the geometry data. For convenience, plunger mass and volume are included in the plunger database. The user may also access the materials database to fill the plunger and housing material edit boxes with appropriate values. Note that only the parameters actually used by the computational portion of the code are enabled for user input. Since the plunger density and the shear strengths are not used, their edit boxes are disabled. The material parameters are shown in Table 4. Of these parameters, all

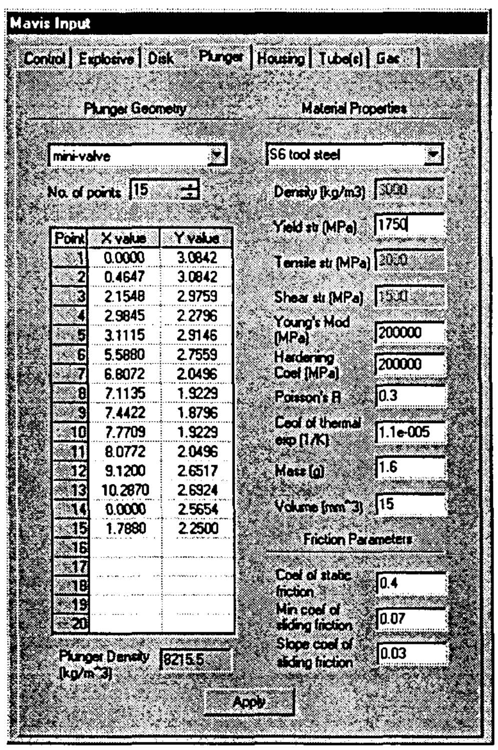


Figure 7: Plunger Page

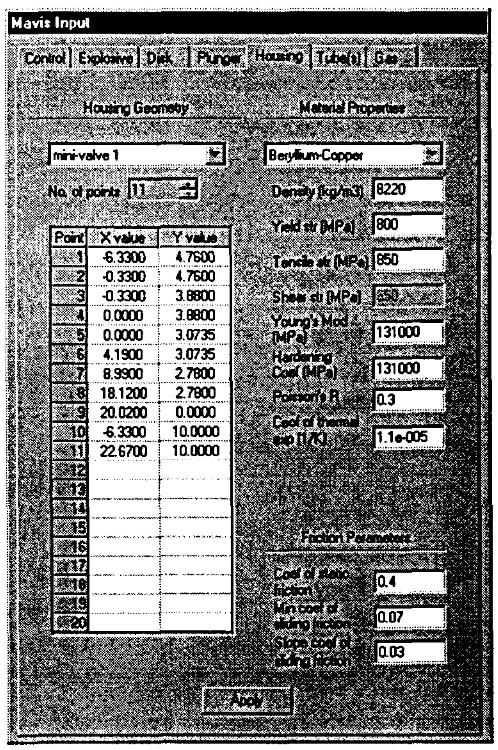


Figure 8: Housing Page

but the hardening coefficient are self-explanatory. The material stress-strain curve in uniaxial tension is modeled with a bilinear approximation as shown in Figure 9.

Table 4: Material Parameters

Parameter	Description
Yield strength	0.2% offset yield strength in uniaxial tension (MPa)
Young's modulus	Elastic modulus (MPa)
Hardening coefficient	The slope of the second linear section of the bilinear approximation to the material stress strain curve (MPa)
Poisson's Ratio	Poisson's ratio (dimensionless)
Coef of thermal expansion	Coefficient of thermal expansion ($1 / C^o$)

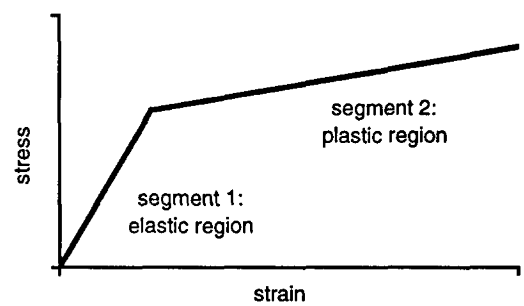


Figure 9: Material Model

The first segment represents the elastic material region and is defined by the elastic modulus and yield strength. The second segment represents the plastic region and is defined by the endpoint of the elastic region and the hardening coefficient. The hardening coefficient is the slope of segment 2. The housing material parameters also include the ultimate tensile strength. Although the user may enter a value in this edit box, it is not currently used during the computational part of the program. It is intended as input for a plunger "nose perimeter force" which is applied when the plunger nose diameter is greater than the corresponding housing bore diameter.

The plunger description includes two parameters that are not found in the housing description, mass and volume. Although the geometry and density might have been used to calculate the plunger mass, a direct user definition is more accurate. The volume parameter represents the free volume in the plunger that the actuator gasses fill once the shear disk has ruptured. As a check, the dialog calculates and displays the plunger density. The density is based on the user defined mass and a plunger volume calculated from the geometry data. Note that since the geometry data is a piecewise linear representation and that it may not include all plunger features, the density calculation is only approximate.

The frictional forces generated as the plunger interferes with the housing bore are determined with a simple coulomb friction model where the frictional force is equal to the product of a dimensionless friction coefficient and the normal interface force. The MAVIS friction model uses a coefficient of friction that exponentially decays with increasing velocity. The functional relationship is of the form shown in Figure 10.

$$f = f_{\min} + (f_{static} - f_{\min})e^{-A_f V}$$

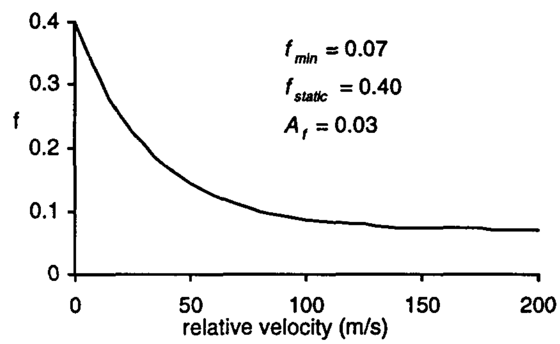


Figure 10: Friction Model

Where f = the friction coefficient, f_{min} = minimum coefficient of sliding friction, f_{static} = the static friction coefficient, A_f = constant (sec/m), and V = velocity (m/sec). The user may change the values of f_{min}, f_{static}, and A_f to create the desired relationship between the coefficient of friction and the velocity. By selecting a large value for A_f, the sliding coefficient of friction becomes constant at the value of f_{min}. Although the friction parameters are displayed in both the plunger and housing dialog pages, they apply only to the plunger and housing interface. Each page provides access to the same data; changing a value in one page changes the corresponding value in the other. The friction parameters are shown in Table 5.

A plot of the functional relationship between the friction coefficient and velocity as defined by the current friction parameters can be viewed by selecting *Friction Plot* from the *View* menu. A typical displayed plot is shown in Figure 11. Entering the desired value in the edit box at the bottom of the plot and clicking Update Axis changes the maximum velocity for the plot.

Clicking the *Apply* button at the bottom of the page stores the entered data and updates the geometry displayed in the main output window. The data is also automatically saved and the geometry updated when the user clicks a dialog tab to activate a different page.

Table 5: Friction Model

Parameter	Description
Coefficient of static friction	The maximum friction coefficient when the relative velocity between the housing and plunger is zero.
Min Coef of sliding friction	f_{min} in the above equation
Slope Coef of sliding friction	A_f in the above equation

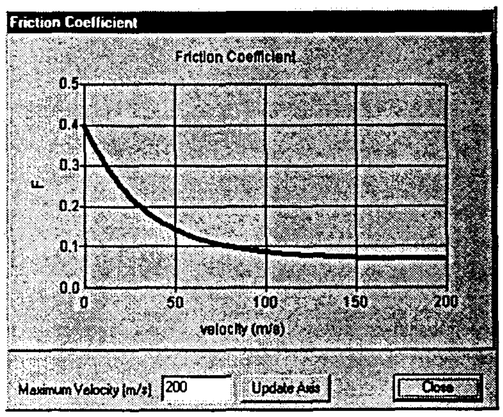


Figure 11: Friction Coefficient Plot

Tube(s)

The *Tube(s)* dialog page is shown in Figure 12. The user may select either one or two tubes by clicking the spinner control in the *Number of Tubes* edit box. If only one tube is selected, the edit boxes for tube number two are disabled. They become enabled when the user selects both tubes.

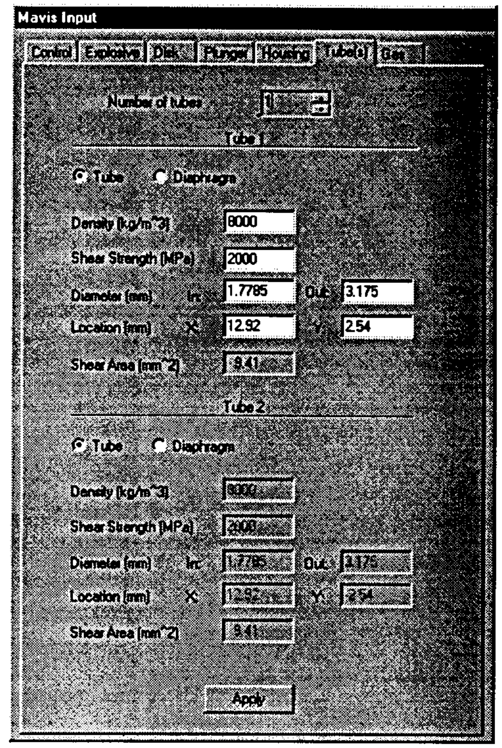


Figure 12: Tube(s) Page

Although the page and sections are labeled with the word *tube*, the dialog allows the user to select either a tube or diaphragm configuration. When a *diaphragm* radio button is selected, the edit boxes and labels in that section change to represent the parameters required for diaphragm definition (an axial location and thickness). Unlike the previous pages, the parameters in the *Tube(s)* page are not linked to a database – they must be manually entered. Six parameters, as described in Table 6, are required for each tube. The material properties include the density in kilograms per cubic meter and the shear strength in mega-pascals. Geometric data includes both a description of the tube cross section and its location in the valve housing. Because the code assumes circular cross-section tubes, only inner and outer diameters (both in millimeters) are required to complete the definition. Entering a x-y coordinate pair in the housing coordinate system specifies the tube location. The user must refer to the housing geometry definition as entered in the *Housing* dialog page to determine the origin of this coordinate system. The coordinate directions are fixed: the x-direction coincides with the bore centerline while the y-value indicates the tube centerline offset from the bore centerline. If a diaphragm is selected, the diameters and the y location are not required; they are replaced with the diaphragm thickness. The dialog also calculates and displays the shear area for the tube or diaphragm, which is based on both the tube/diaphragm and plunger geometry. This shear area calculation is valid only when the tube is positioned so that the plunger intersects the tube's internal flow passage.

Clicking the *Apply* button at the bottom of the page stores the entered data and updates the geometry displayed in the main output window. The data is also automatically saved and the geometry updated when the user clicks a dialog tab to activate a different page.

Table 6: Tube Parameters

Parameter	Description
Density	The tube material density (kg/m^3)
Shear strength	The tube material shear strength (MPa)
Inner diameter	The tube inside diameter (mm)
Outer diameter	The tube outside diameter (mm)
X location	The tube or diaphragm axial position relative to the housing coordinate system (mm)
Y location	The offset between the tube centerline and the housing bore centerline (mm)
Thickness	The diaphragm thickness (mm)
Shear Area	The tube or diaphragm shear area (mm^2) - calculated

Gas

The *Gas* dialog page is shown in Figure 13. With this dialog the user enters both gas pressure and inertial loads. Gas pressures, their associated additional volumes, and the gas gamma values (ratio of specific heats) for the housing bore and tubes are entered in the *Gas Pressure Loads* section of the dialog. The bore pressure is applied to the plunger forward-facing area and produces a force directed toward the actuator. As it travels, the plunger compresses this trapped gas and increases the force. Once the tubes are cut, their contained gas further adds to the bore pressure and the plunger force. To simplify the gas pressure calculations, MAVIS assumes immediate pressure equilibrium and ignores transient gas flow from the additional volumes through the tubes.

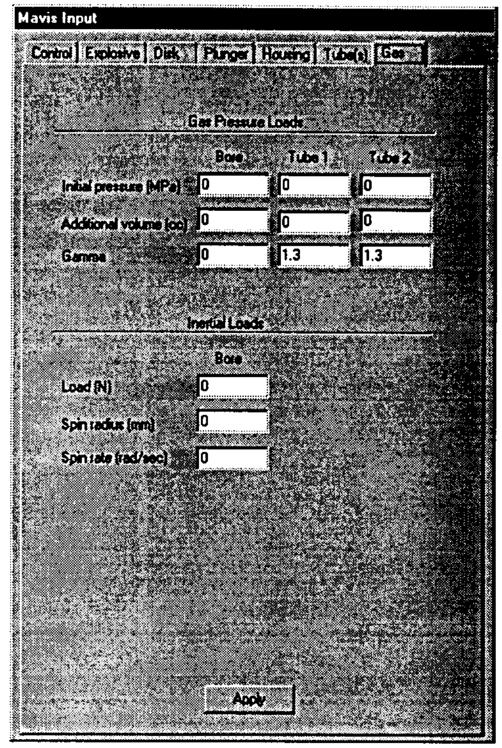


Figure 13: Gas Page

The user may specify both a directly applied plunger load and loads induced by a spin environment. A positive load is directed down-bore while a negative load is directed toward the actuator. For spin loads, MAVIS assumes that the housing centerline always intersects the center of rotation. Therefore, only axial acceleration is considered. Lateral accelerations that produce non-axisymmetric interface forces are not accounted for. A positive spin-radius develops a plunger retarding force while a negative spin-radius aids plunger acceleration.

Table 7 summarizes the parameters in the *Gas* dialog page.

Table 7: Gas Parameters

Parameter	Description
Initial pressure	The initial pressure in either the bore, tube 1, or tube 2 (MPa)
Additional volume	The additional volumes associated with the above pressures (cc)
Gamma	The ratio of specific heats for the trapped gas
Load	The directly applied load that retards plunger acceleration down the housing bore (N)
Spin radius	The distance between the housing coordinate system origin and the center of rotation (mm)
Spin rate	The rotational velocity (rad/sec)

Parameter Slider Dialog

In addition to using the tabbed input dialog pages, the user may change valve parameter values with the *Parameter Slider* dialog as shown in Figure 14. This dialog is displayed by choosing *Create Slider* from the *Options* menu. The dialog contains a list box with all valve parameters, a slider control with edit boxes that display the minimum, current, and maximum slider values, and *Set Slider* and *Close* buttons. The dialog is initially presented with an inactive slider. The user activates the slider by selecting a valve parameter in the list box, either by double-clicking the item or by highlighting it and subsequently clicking the *Set Slider* button. Selecting the item causes the slider edit boxes to be filled the current parameter value, 50% of the current value (minimum), and 150% of the current value (maximum). When the user releases the mouse button after changing the current parameter value by moving the slider, a new calculation is initiated and the display is refreshed with the results. The user may reset the minimum and maximum slider values to 50% and 150% of the current value at any time by clicking the *Set Slider* button. The user may also independently select the minimum and maximum slider values by typing the desired values directly into the appropriate edit boxes. The current parameter value adjusts accordingly as the minimum and maximum values change. As is the case with the input tabbed dialog, only the parameter slider dialog for the currently selected child window is displayed.

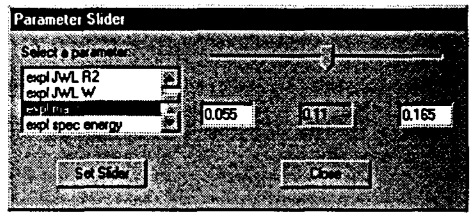


Figure 14: Parameter Slider Dialog

Main Output Window

The main output window contains two panes, the geometry pane and the graph pane as shown in Figure 15. These panes are part of a *splitter window* and are separated by a *splitter bar*. The user may drag the splitter bar up or down to reallocate window space to each pane. In addition, the user may resize the entire main window by dragging its frame. The geometry and graph displays automatically resize as the window grows or shrinks.

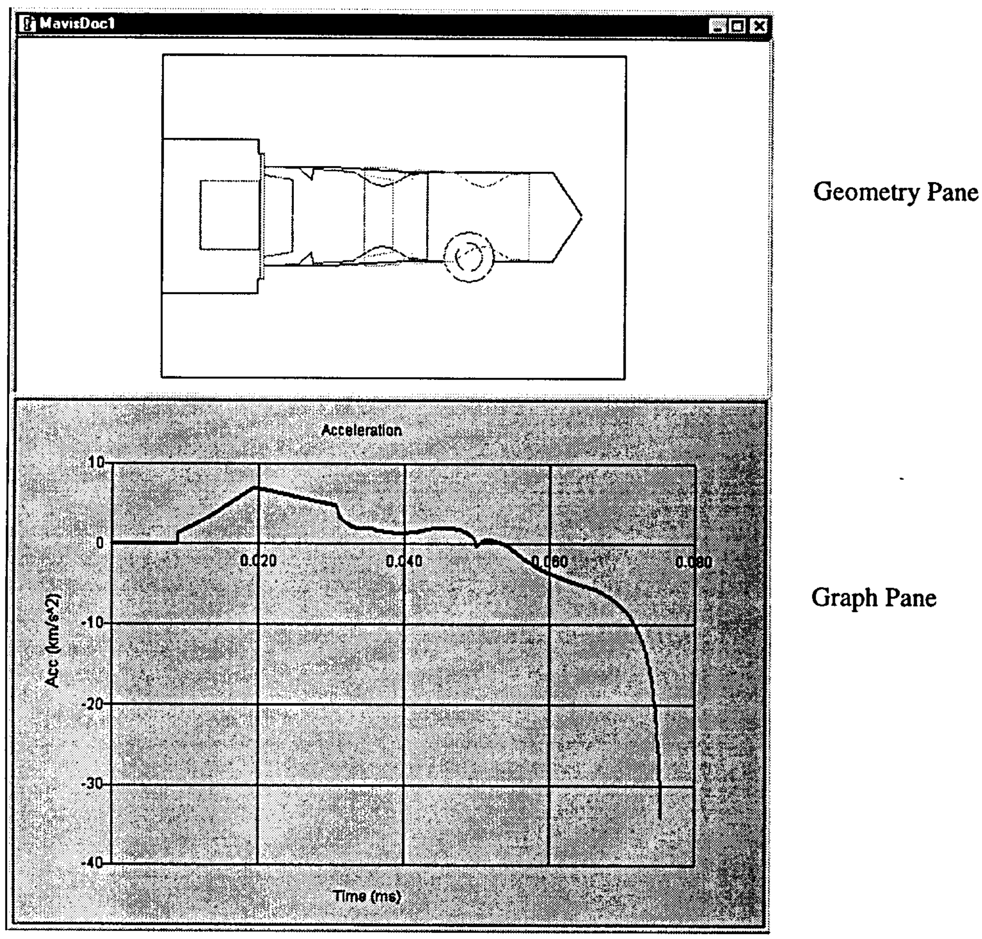


Figure 15: Main Output Window

Geometry Pane

The geometry pane displays the geometric data entered in the pages of the tabbed dialog and acts as a visual indication of data integrity. As geometry data changes and is applied, either by clicking an *Apply* button or activating a different dialog page, the geometry display automatically updates. In addition, when a calculation successfully completes, the plunger is drawn in its post-function position. To print the geometry display, the geometry pane must be currently selected (by clicking anywhere in the pane).

Graph Pane

The graph pane provides access to plots that display plunger kinetic information. When the user clicks anywhere in the graph pane it becomes active and the *Plot* menu and graph-related toolbar buttons are enabled. The *Plot* menu, shown in Figure 16, allows the user to select one of sixteen plots for display. In addition, the user can select whether to plot these quantities against time or against the plunger position (stroke). The available plots are described in Table 8.

Table 8: Available Plots

Parameter	Description
Acceleration	The plunger acceleration
Velocity	The plunger velocity
Stroke	The plunger position
Expl pressure	The pressure of the explosive gases
Volume	The volume behind the plunger
Expl force	The plunger force due to explosive gas pressure
Loss force	The sum of disk, drag, cutting, and gas forces
Total force	The sum of explosive force and loss force
Drag force	The frictional force at the plunger-housing interface
Cutting force	The tube cutting forces.
Gas force	The trapped gas pressure forces
Plunger	Combined velocity and stroke
Explosive	Combined explosive pressure and volume
Forces	Combined total, explosive, and loss forces
Losses	Combined drag, cutting, and loss forces

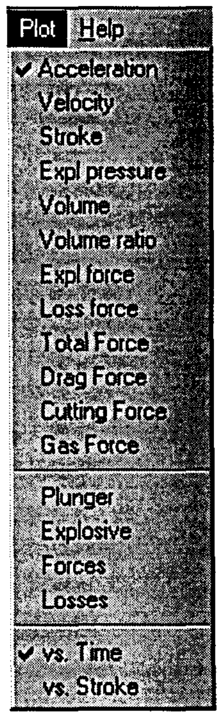


Figure 16: Plot Menu

As an alternative to selecting a plot through the *Plot* menu, the user may iterate through the plot list by clicking the previous and next arrow buttons on the toolbar shown in Figure 17.

Right-clicking on the graph reveals the Graph Control property pages, as shown in Figure 18, and allows the user to interactively change the graph's appearance. The large number of available pages provides access to almost all graph characteristics. Note, however, that changes made to one graph affect all others. To print the graph display, the graph pane must be currently selected (by clicking anywhere in the pane).

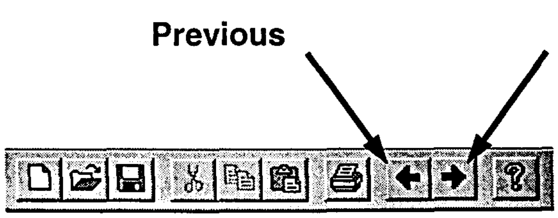


Figure 17: Toolbar

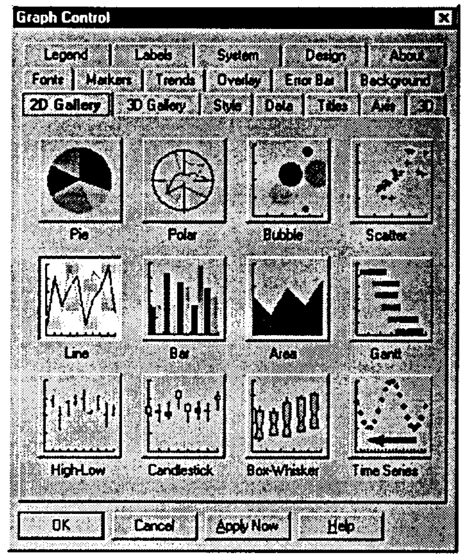


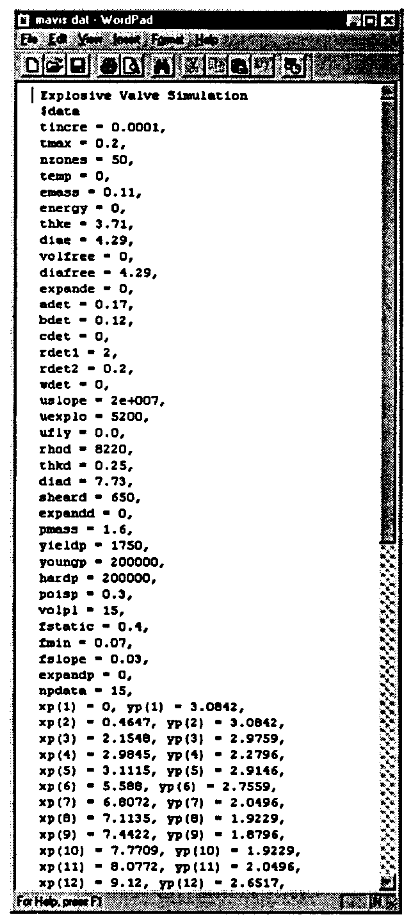
Figure 18: Graph Control Property Pages

Viewing the Input and Output Files

The files input to and written by the MAVIS computational program can be viewed by selecting the desired items from the three presented in the *View* menu. The user may select either the last generated (current) input file, summary report file, or plot data file. Because each calculation overwrites the files generated during the previous calculation, only the most recent file sets are available. For simplicity and expediency, the current version of MAVIS uses the Windows accessory *WordPad* to display the files. Note that an open *WordPad* will not receive notice that the file it is displaying has been modified. If a new calculation is performed while *WordPad* is displaying a file, that display will not be updated. Therefore, to ensure that the most recent file is being viewed, the user should close currently running *WordPads* before selecting an item from the *View* menu. Future versions of MAVIS might include an integral file viewer.

Input File

The input file, *Mavis.dat*, is a Fortran *namelist* formatted text file read by the MAVIS computational program. It may be viewed by selecting *Current Input File* from the *View* menu. MAVIS then starts *WordPad* and loads the last input file generated. The file contents may be manipulated, including saved and printed, with the normal *WordPad* commands. A sample display is shown in Figure 19.




```
Explosive Valve Simulation
$data
tincre = 0.0001,
tmax = 0.2,
nzones = 50,
temp = 0,
emass = 0.11,
energy = 0,
thke = 3.71,
diae = 4.29,
volfree = 0,
diafree = 4.29,
expande = 0,
adet = 0.17,
bdet = 0.12,
cdet = 0,
rdet1 = 2,
rdet2 = 0.2,
wdet = 0,
uslope = 2e+007,
uexplo = 5200,
ufly = 0.0,
rhod = 8220,
thkd = 0.25,
diad = 7.73,
sheard = 650,
expandd = 0,
pmass = 1.6,
yieldp = 1750,
youngp = 200000,
hardp = 200000,
poisp = 0.3,
volpl = 15,
fstatic = 0.4,
fmin = 0.07,
fslope = 0.03,
expandp = 0,
npdata = 15,
xp(1) = 0, yp(1) = 3.0842,
xp(2) = 0.4647, yp(2) = 3.0842,
xp(3) = 2.1548, yp(3) = 2.9759,
xp(4) = 2.9845, yp(4) = 2.2796,
xp(5) = 3.1115, yp(5) = 2.9146,
xp(6) = 5.588, yp(6) = 2.7559,
xp(7) = 6.8072, yp(7) = 2.0496,
xp(8) = 7.1135, yp(8) = 1.9229,
xp(9) = 7.4422, yp(9) = 1.8796,
xp(10) = 7.7709, yp(10) = 1.9229,
xp(11) = 8.0772, yp(11) = 2.0496,
xp(12) = 9.12, yp(12) = 2.6517,
```

Figure 19: Input File Display

Summary Report

The summary report file, *Mavis.out*, which contains all user input values and a summary of plunger stroke, travel time, restroke force, and maximum velocity, is displayed by selecting *Current Report* from the *View* menu. MAVIS then starts *WordPad* and loads the last report generated. The report may be manipulated, including saved and printed, with the normal *WordPad* commands. A sample summary report is shown in Figure 20.

Plot Data File

The plot data file, *Mavis.raw*, is a formatted text file that contains the numerical data used to generate the plots in the graph pane of the main output window. It is displayed by selecting *Current Plot Data* from the *View* menu. MAVIS then starts *WordPad* and loads the last plot file generated. The file contents may be manipulated, including saved and printed, with the normal *WordPad* commands. A sample display is shown in Figure 21.

```
M           A                  V    I       S          II
Modeling and Analysis of explosive Valve InteractionS

 .........             title :    Valve Simulation
 tincre= 0.00010 ms  tmax=    1.0000 ms  noprint=0  nzones= 50  temp=  0. deg k
 ----------------------------------------------------------------------------
   E X P L O S I V E                     j-w-l coefficients
 emass= 0.110 grams  (vol=   53.63 mm3)  adet=  0.170 mj/kg  energy=  0.0 mj/kg
 (rhoe=2051. kg/m3)  thke=     3.710 mm  bdet=  0.120 mj/kg
                     diae=     4.290 mm  cdet=  0.000 mj/kg  uslope=2.E+07 m/s2
 expande= 0.00E+0/k  volfree=  0.00 mm3     rdet1=  2.00     uexplo= 5200.  m/s
                     (thkfree= 0.00 mm)     rdet2=  0.20     (t-rise= 0.019 ms)
 ufly=     0.00 m/s  diafree=  4.290 mm     wdet =  0.00     (t-burn= 0.019 ms)
 ----------------------------------------------------------------------------
   D I S C                                                      *shear*
 (mass= 0.06 grams)  thkd=     0.250 mm  sheard=   650. MPa  (area=   4.84 mm2)
 rhod= 8220.0 kg/m3  diad=     7.730 mm  expandd= 0.00E+0/k  (force=  3149.0 n)
 ----------------------------------------------------------------------------
   P L U N G E R
 pmass=  1.60 grams  yieldp=  1750. MPa  youngp=200000. MPa  volpl=   15.00 mm3
 (rhop=7028. kg/m3)  poisp=       0.300  hardp= 200000. MPa  cfact=          0.
 npdata= 15 xp()-yp()                (zone size = 0.2057 mm)  expandp= 0.00E+0/k
  1)  0.000 - 3.084   2)  0.465 - 3.084   3)  2.155 - 2.976   4)  2.984 - 2.280
  5)  3.112 - 2.915   6)  5.588 - 2.756   7)  6.807 - 2.050   8)  7.114 - 1.923
  9)  7.442 - 1.880  10)  7.771 - 1.923  11)  8.077 - 2.050  12)  9.120 - 2.652
 13) 10.287 - 2.692  14)  0.000 - 2.565  15)  1.788 - 2.250
 ----------------------------------------------------------------------------
   H O U S I N G
                     yieldh=   800. MPa  youngh=131000. MPa  fstatic=      0.400
 rhoh=  8220. kg/m3  poish=       0.300  hardh= 131000. MPa  fmin =        0.070
 xmaxi=      22.670                      surfh=     0.000 u  fslope=       0.010
 nhdata= 11 xh()-yh()                                        expandh= 0.00E+0/k
  1) -6.330 - 4.760   2) -0.330 - 4.760   3) -0.330 - 3.880   4)  0.000 - 3.880
  5)  0.000 - 3.073   6)  4.190 - 3.073   7)  8.990 - 2.780   8) 18.120 - 2.780
  9) 20.020 - 0.000  10) -6.330 -10.000  11) 22.670 -10.000
 ----------------------------------------------------------------------------
   T U B E S         1 tubes/punch in the design
                             1          2          3          4          5
                            TUBE
 rhot()         kg/m3      8000.        0.         0.         0.         0.
 diaot()           mm      3.175      0.000      0.000      0.000      0.000
 diait()           mm      1.778      0.000      0.000      0.000      0.000
 (shear area)     mm2       9.42       0.00       0.00       0.00       0.00
 sheart()         MPa      2000.        0.         0.         0.         0.
 xt()              mm     12.920      0.000      0.000      0.000      0.000
 yt()              mm      2.540      0.000      0.000      0.000      0.000
 expandt()         /k    0.00E+0    0.00E+0    0.00E+0    0.00E+0    0.00E+0
 pt()             MPa        0.0        0.0        0.0        0.0        0.0
 vt()             mm3    0.00E+0    0.00E+0    0.00E+0    0.00E+0    0.00E+0
 gt()                       1.30       1.00       1.00       1.00       1.00
 ----------------------------------------------------------------------------
   G A S ,  SPIN Loads
 pgas=     0.00 MPa  vadd=  0.00E+0 mm3  (vgas= 0.21E+3mm3)  gamma=        0.000
 gload=       0.000  gradius=     0.000  gspin=       0.000
 ----------------------------------------------------------------------------
 ----------------------------------------------------------------------------

                    Valve Simulation


           STROKE is   5.35 mm ( 0.211 in.), reached in   0.0674 msec
           Restroke Force will be  48257.3 N  (Pressure of 1980.42 MPa)

           Max. VELOCITY is   143.453 m/s  at   0.0521 msec
```

Figure 20: Summary Report

mavis.raw - WordPad

File Edit View Insert Format Help

756

cycle	time (sec)	acc (m/s^2)	vel (m/s)	pos (mm)	P-act (MPa)	Vol (cc)	Vol ratio	Exp Force (N)
1	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.53626E+02	0.10000E+01	0.00000E+00
2	0.10000E-03	0.00000E+00	0.00000E+00	0.00000E+00	0.16034E-01	0.53626E+02	0.10000E+01	0.47915E+00
3	0.20000E-03	0.00000E+00	0.00000E+00	0.00000E+00	0.64135E-01	0.53626E+02	0.10000E+01	0.19166E+01
4	0.30000E-03	0.00000E+00	0.00000E+00	0.00000E+00	0.14430E+00	0.53626E+02	0.10000E+01	0.43124E+01
5	0.40000E-03	0.00000E+00	0.00000E+00	0.00000E+00	0.25654E+00	0.53626E+02	0.10000E+01	0.76664E+01
6	0.50000E-03	0.00000E+00	0.00000E+00	0.00000E+00	0.40085E+00	0.53626E+02	0.10000E+01	0.11979E+02
7	0.60000E-03	0.00000E+00	0.00000E+00	0.00000E+00	0.57722E+00	0.53626E+02	0.10000E+01	0.17249E+02
8	0.70000E-03	0.00000E+00	0.00000E+00	0.00000E+00	0.78566E+00	0.53626E+02	0.10000E+01	0.23478E+02
9	0.80000E-03	0.00000E+00	0.00000E+00	0.00000E+00	0.10262E+01	0.53626E+02	0.10000E+01	0.30666E+02
10	0.90000E-03	0.00000E+00	0.00000E+00	0.00000E+00	0.12987E+01	0.53626E+02	0.10000E+01	0.38811E+02
11	0.10000E-02	0.00000E+00	0.00000E+00	0.00000E+00	0.16034E+01	0.53626E+02	0.10000E+01	0.47915E+02
12	0.11000E-02	0.00000E+00	0.00000E+00	0.00000E+00	0.19401E+01	0.53626E+02	0.10000E+01	0.57977E+02
13	0.12000E-02	0.00000E+00	0.00000E+00	0.00000E+00	0.23089E+01	0.53626E+02	0.10000E+01	0.68998E+02
14	0.13000E-02	0.00000E+00	0.00000E+00	0.00000E+00	0.27097E+01	0.53626E+02	0.10000E+01	0.80977E+02
15	0.14000E-02	0.00000E+00	0.00000E+00	0.00000E+00	0.31426E+01	0.53626E+02	0.10000E+01	0.93914E+02
16	0.15000E-02	0.00000E+00	0.00000E+00	0.00000E+00	0.36076E+01	0.53626E+02	0.10000E+01	0.10781E+03
17	0.16000E-02	0.00000E+00	0.00000E+00	0.00000E+00	0.41047E+01	0.53626E+02	0.10000E+01	0.12266E+03
18	0.17000E-02	0.00000E+00	0.00000E+00	0.00000E+00	0.46338E+01	0.53626E+02	0.10000E+01	0.13847E+03
19	0.18000E-02	0.00000E+00	0.00000E+00	0.00000E+00	0.51950E+01	0.53626E+02	0.10000E+01	0.15525E+03
20	0.19000E-02	0.00000E+00	0.00000E+00	0.00000E+00	0.57882E+01	0.53626E+02	0.10000E+01	0.17297E+03

For Help, press F1

Figure 21: Plot File Display

Miscellaneous

Code Limitations

MAVIS currently performs only minimal input value checks. As a result, if the user errs when entering values, the MAVIS computational routines may receive data that is not completely appropriate. Depending upon the nature of the error, the computation may complete and provide erroneous output data that can generally be identified in the output plots. On the other hand, since several routines are iterative and return only upon successful numerical convergence, the computation may enter an endless loop of calculations. If the calculation does not complete in a short amount of time (a few seconds), the user can open the computational message output window by clicking on the MavisSG1 button on the taskbar. If the calculation is experiencing difficulty, a message may be displayed in this window. Note that the taskbar button is available only while the computational routines are executing. While future versions of MAVIS may implement a more complete input-checking algorithm, the current version places the responsibility for ensuring consistent input primarily upon the user.

Software Description

This section briefly describes the MAVIS software development philosophy and structure. The intent of recording this information is to provide future developers with the basis needed for code debugging or upgrading.

Development Environment

The MAVIS upgrade was developed on a Windows NT PC using the Microsoft Visual Studio 97 integrated development environment (IDE)[3]. Visual Studio 97 provides an environment that enables a developer to efficiently write, test, and debug code. All C and C++ code was compiled with Microsoft's Visual C++ 5.0 compiler while the Fortran was compiled with Digital Visual Fortran 5.0 compiler[4].

Code Structure

MAVIS contains three executable files, *Mavis.exe*, *MavisSG1.exe*, and *Sgw32.exe*. *Mavis.exe* is the executable image created by compiling and linking the C++ user interface code while *MavisSG1.exe* is the image created by compiling and linking the Fortran computational code. *Sge32.exe* is a local automation server that produces the plots in the graph pane of the main output window. The user runs MAVIS by running the interface image. When the *Control* dialog's *Calculate* button is clicked, the user interface runs the computational code by spawning a new synchronous process. When the computational code terminates, the system destroys that process and returns control to the interface code. With this structure, the interface and computational codes run in separate process spaces and do not share memory.

The described structure was selected for one primary reason. The original Fortran MAVIS console application, from which the computational code was derived, used very little interactive user input. Rather, all important inputs were provided in a namelist formatted text file. Additionally, the code wrote all important output data to similar text files. This file I/O configuration of the original MAVIS provided a simple means of file-based communication between the interface and computational codes and required a minimum of Fortran source modification. *Mavis.dat* is the input file written by the interface while *Mavis.out* and *Mavis.raw* are the summary report and plot data files written by the computational routines.

Computational Code

As previously mentioned, the finished computational code is a minimal modification of the original Fortran MAVIS application and is itself an executable application. The modifications, which are documented in the source code, include the creation of a "once-through" program flow to replace the original looping flow controlled by interactive user input. Minor syntactic changes were made to file opening statements and all

[3] Microsoft Corporation, One Microsoft Way, Redmond, Washington 98052-6399, http://www.microsoft.com
[4] Digital Equipment Corporation, Maynard, Massachusetts, http://www.dec.com

non-essential screen output was eliminated. Further, Fortran statements were added to access the Visual Fortran QuickWin run-time library, which adds some windowing capabilities to the application. These statements prevent the application from displaying a window when it executes. Rather, the application window is minimized and is visible only as a taskbar button. While it is active, however, the user may click the button to expand the window. The computational segment was built as a *Standard Graphics* application using the Visual Studio 97 AppWizard. A Standard Graphics configuration was chosen because it supports the QuickWin library routines and allows the window to be minimized at execution.

When it executes, the code expects to find a namelist formatted text file called *Mavis.dat* in the same directory in which it resides. If the file is not present, the code will not execute successfully. During execution, the code writes two files: *Mavis.out*, which contains text-based summary report and *Mavis.raw*, which contains the text-based plot data.

User Interface Code

The user interface code, written in C++, was built using Visual Studio's MFC (Microsoft Foundation Class) AppWizard as a MDI (multiple document interface) application. The Microsoft Foundation Classes provide object-oriented wrappers around most of the Windows 95/NT API (application programming interface) routines while the MDI architecture allows a user to concurrently work on several MAVIS documents. The finished interface code comprises many classes, some of which were generated by the AppWizard, most of which were developer-generated, and some of which were generated by the inclusion of software components (ActiveX controls). The classes are summarized in Table 9. Some of the more interesting classes are described in more detail below.

Property Sheet and Page Classes

The property sheet is the tabbed dialog that contains each of the seven property pages. Aside from its normal base class implementation, the property sheet does little more than funnel application specific instructions to the property pages. For example, when the property sheet receives *Serialize* and *WriteInputFile* commands it simply passes them on to the individual pages.

Instead of the inputs being transferred to the document and stored communally, all data entered in a property page is stored in that page's member variables. Each page implements common functionality, including the maintenance of its own display, data transfer from the database record sets to the member variables, input file generation, and serialization. Display maintenance includes routine tasks such as filling the edit boxes with appropriate values, enabling and disabling various controls, and storing edit box data to the member variables. Data base transfer is accomplished by simply transferring data from each record set variable to a corresponding property page member variable. The computational routine input file (*Mavis.dat*) is written when the property sheet instructs each page to write its data to the file by issuing a *WriteInputFile* command. Finally, each property page is responsible for storing and restoring its own data and therefore implements its own *Serialize* method. A simple schema number written to the data file provides for future backward compatibility.

The *Plunger* and *Housing* property pages contain a software component not found in the other pages: the grid edit structure used to enter geometric data. Although the *MSFlexGrid* ActiveX component, which is included with Visual Studio 97, is intended for Visual Basic applications, the environment is able to wrap it

Table 9: User-Interface Classes

Table 9

Class name	Description
CAboutDialog	The *About Mavis* dialog class. This dialog is displayed from the *Help* menu.
CActuatorRecSet	A record set class that provides a communication path to the actuator database
CChildFrame	The applications main output frame window class. The splitter window resides in this frame. The geometry and graph views are children of the splitter window.
CControlPP	The *Control* dialog (property page) class
CDiskPP	The *Disk* dialog (property page) class
CDiskRecSet	A record set class that provides a communication path to the disk database
CExplosivePP	The *Explosive* dialog (property page) class
CGasPP	The *Gas* dialog (property page) class
CHousingPP	The *Housing* dialog (property page) class
CHousingRecSet	A record set class that provides a communication path to the housing database
CInputPS	The input tabbed dialog (property sheet) class
CMainFrame	The main frame class
CMaterialRecSet	A record set class that provides a communication path to the material database
CMavisApp	The application class
CMavisDoc	The document class
CMavisGraphView	The view class that displays the graphical kinetic information
CMavisView	The view class that displays the valve geometry
CMSFlexGrid	The grid edit structure class used to enter plunger and housing geometry data
CPlungerPP	The *Plunger* dialog (property page) class
CPlungerRecSet	A record set class that provides a communication path to the plunger database
CSplashWnd	The splash screen class
CTubePP	The *Tube(s)* dialog (property page) class

with a C++ interface, rendering it available to the C++ developer. Unfortunately, the raw component does not implement an interactive editing capability – it is intended only for data display. However, some tricky coding with a dynamically positioned topmost edit box delivers the required functionality in an effective, if not graceful, manner.

Database Classes

MAVIS database access is built upon Data Access Object (DAO) classes rather than Open Database Connectivity (ODBC). Using DAO provides a more object-oriented access and does not require that the databases be registered with the system (although the code must still know where to find them). The five record set classes are derived from *CDAORecordset* and provide this access to the Microsoft Access databases (**.mdb*). Most of the functionality is provided as the classes are built with the ClassWizard. Each class's *DoFieldExchange()* method actually performs the data transfer from the database fields to the record set member variables.

View Classes

The two view classes, *CMavisView* and *CMavisGraphView* fill the splitter-window panes in the main output window with valve geometry and kinetic data plots, respectively. These view classes implement the functionality required to draw and print their respective displays. Each also implements methods for obtaining pointers to each of the property pages and hence the page's public member variable data. For ease of access without friend classes, if not for sound object-oriented development practices, all property page member variables are declared public.

The geometry view reads the geometric data from each page and draws the valve display by executing the *DrawHousing*, *DrawPlunger*, *DrawDisk*, *DrawTube*, and *DrawActuator* methods in its *OnDraw* method. The *OnDraw* method, of course, is called whenever the display requires updating. The view also implements window and viewport mapping to ensure that the image fills the view area.

The *MavisGraphView* plots are generated with a purchased software component called *Graph Control.*[5] Like the *MSFlexGrid*, this ActiveX control is intended for use with Visual Basic applications and was wrapped by the system with a C++ interface. Most of the difficult graphical work is performed by the control itself. The view class is responsible, however, for defining the initial graph appearance, loading the graph with the appropriate data, resizing the graph as the view pane grows or shrinks, and issuing print commands in response to user print requests.

Databases

MAVIS accesses five databases to simplify data entry in the property pages. As previously mentioned, access is provided by *CDAORecordset* derived classes, one for each database. The databases that MAVIS uses were constructed with Microsoft Access 97 database management system. The database structures are simple – each contains a single table with one field for each data value. These structures are summarized in Tables 10 through 14.

This version of MAVIS does not allow the user to transfer data from the property pages to the databases for later recall. The intent of imposing this limitation is to avoid contaminating the database with bad data. Note that no access control is placed on the databases themselves. A user may alter the databases directly by running Microsoft Access. Also note that a database structure change will confuse the record set classes that are responsible for managing data transfer. Data base changes should be limited to the addition or deletion of records. A future version of MAVIS might include a password-controlled mechanism for allowing data to be transferred from the property pages to the databases.

[5] Graph Control, Pinnacle Publishing, Inc. PO Box 888, Kent, WA 98035-0888, (425) 251-1900, Fax (425) 252-5057, http://www.pinpub.com

Table 11: Actuators Database

Database file: actuators.mdb
Table: explosives

Field	Data Type
ID	long integer
name	text
mass	single
specific_energy	single
thickness	single
diameter	single
free_vol	single
free_vol_dia	single
coef_t_expand	single
jwl_a	single
jwl_b	single
jwl_c	single
jwl_r1	single
jwl_r2	single
jwl_w	single
jwl_slope	single
jwl_ssvel	single

Table 12: Materials Database

Database file: materials.mdb
Table: mech_props

Field	Data Type
ID	long integer
name	text
density	single
yield_strength	single
ultimate_strength	single
youngs_modulus	single
hardening_coef	single
poisson	single
shear_strength	single
coef_t_expand	single

Table 10: Housing Database

Database file: housing.mdb
Table: geometry

Field	Data Type
ID	long integer
name	text
numPoints	single
X1	single
...	
X20	single
Y1	single
...	
Y20	single

Table 14: Plunger database

Database file: plunger.mdb
Table: geometry

Field	Data Type
ID	long integer
name	text
volume	single
mass	single
numPoints	single
X1	single
...	
X20	single
Y1	single
...	
Y20	single

Table 13: Disks Database

Database file: disks.mdb
Table: geometry

Field	Data Type
ID	long integer
name	text
thickness	single
diameter	single

File Viewing

As previously mentioned, MAVIS permits the user to view files that contain the input data, summary information, and plot data. MAVIS accomplishes this task by simply instructing the operating system to spawn a new *Wordpad* process with the target file name as a command line argument. The primary benefits of this method are that it is exceedingly simple from a programming viewpoint and the user gains all of the functionality of *Wordpad*, including the ability format, cut, paste, preview, and print the file contents. On the other hand, this method has a shortcoming. Because the MAVIS process and the *Wordpad* process are independent and share no data, MAVIS does not instruct *Wordpad* to update its contents as the file changes. Therefore, if the *Wordpad* file viewer is open when the displayed file contents change, the displayed information will no longer be current. A better method of allowing the user to view the file contents should be implemented in the next upgrade, either by embedding a *Wordpad* object into the MAVIS application or by incorporating a rich-text control as a simple viewer. In both cases, the viewer could easily be notified of file contents changes and could respond by re-reading the file and displaying the current information.

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